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Cloud Networking: Implications of Agile virtualization on Provider Relationships

Pedro A. Aranda Gutiérrez[1] **and Jorge Carapinha**[2]

[1]paag@tid.es
Telefónica I+D
C./Emilio Vargas,6
ES-28034 Madrid

[2]JorgeC@ptinovacao.pt
PT Inovação
Rua Eng. José Ferreira Pinto Basto
Aveiro - Portugal

Abstract: SAIL is a Framework Programme 7 project that aims at providing scalable and adaptive solutions to enhance the Internet Although not a formal continuation of the 4WARD project, SAIL integrates many of the advanced concepts developed there. One of the focuses of the project, *Cloud networking* (CloNe), can be conceived as the successor of the Virtual Networks activities in 4WARD. This article concentrates on the initial discussions on the proposed model for Cloud networking (CloNe) and the implications it has for inter-provider relationships in the SAIL Framework.

Keywords: Virtualization, Network management, Inter-Provider relationships

1 Introduction

The SAIL project [The10] has started in August, 2010 in the 4^{th} call of the 7^{th} Framework Programme of the European Union. Although not a continuation of the 4WARD project [The08] *strictu sensu*, SAIL integrates and further enhances concepts explored in 4WARD. One of these concepts is virtualization. 4WARD recognised many of the short-comings of virtualization solutions in the market and proposed new ways of virtualizing networks. The objective in SAIL is to continue exploring Future Internet concepts and find ways to deploy them in current networks, thus accelerating their adoption and the transition to the Network of the Future. As far as virtualization is concerned, SAIL plans to explore new concepts that distribute virtualization all over the network and provide a more responsive and efficient solution to network related virtualization scenarios. The strategy followed in SAIL is to tackle the Future Internet from three different views or based on three technological pillars which are interrelated. SAIL explores advances in the Network of Information world in order to efficiently deliver contents to users. In order to do so, Open Connectivity Services are developed which enable the delivery of Cloud networking as the unification of virtualization techniques at network and resource level, building on resource mobility concepts developed by 4WARD.

One of the findings of 4WARD was that all components related with virtualization cannot be efficiently implemented and provided in a monolithic operator model. Operators need to implement different roles that describe their relationship with the virtualized resource. In such a model, cooperation and specialisation can mobilise significant synergies. A network model with provider roles was therefore proposed. In this model, a provider can decide to implement a subset of roles and cooperate with other providers to implement the full network model. This cooperation can be on an on-demand basis.

Current virtualization technologies provide reasonable solutions for non distributed Data Centre solutions where the traffic is highly localised within the Data Centre and the network configuration is highly stable in time. In order to provide a more efficient network, SAIL aims at providing a novel cloud networking solution based on flash network slices where computing and storage is distributed along the network. This novel approach will demand a network infrastructure that copes well with changes highly dynamical and volatile network configurations .

This paper is structured as follows: Section 2 presents the State of the Art in Network virtualization, including the provider model developed in the 4WARD project, Section 3 presents the provider interaction concepts that are going to be explored in the SAIL project and Section 4 presents the conclusion.

2 State of the Art

The ever-increasing levels of accessibility to broadband access have made it possible to provide network based computing and storage resources which can be accessed anytime and anywhere. This apparently seamless access has created the metaphor of 'Cloud' services. All these services have a profound rooting in virtualization techniques.

Virtualization, both in the computing and in the networking world, has been used for a long time. In the computing world, virtualization is understood as executing software in an environment that is separated from the hardware it is executed on. The communications world stresses on logical separation of different communications over a common physical communications layer. Multi-Protocol Label Switching (MPLS) is an example of network virtualization that comprises sharing links and nodes in order to deploy logically isolated networking infrastructures. MPLS uses many of the concepts developed for Asynchronous Transfer Mode (ATM) and Frame Relay (FR) previously. These two technologies are considered link or layer-2 virtualization techniques, where the nodes share a common control plane. MPLS also includes the possibility to create logically separated, concurrent routing (IP-Layer switching) instances in the nodes, which are used to provide Virtual Private Networks (VPNs) [RR06].

Another advance in the computing front that brought cloud networking nearer was clustering. Clustering solutions like Beowulf [Beo09b] allowed off-the-shelf computing hardware to be connected over a Local Area Network (LAN) or Storage Area Network (SAN) to be interconnected to produce High Performance Computing (HPC) nodes. Additionally to HPC, where clusters are used to provide greater computational power than a single computer can provide, clusters are also used for High Availability (HA) when greater reliability is needed. The Beowulf clustering software is a popular open-sourced clustering solution, as the list of projects using it [Beo09a] demonstrates.

A next step in complexity regarding the distribution of resources is the concept of *Grid Computing* [Buy09]. A comprehensive study of the different types of Data Grids was provided by Venugopal et. al. in [VBR06]. This article also delimits the scope of Data Grids compared to other data sharing and distribution paradigms such as Content Delivery Networks (CDNs), Peer-to-Peer Networks (P2Ps), and distributed databases. The 'grid' metaphor mainly reflects the fact that the resources involved have a static behaviour, i.e. the underlying network topology is not changed often. Resources include not only computing capacity, but also storage. These resources are interconnected and orchestrated in order to produce distributed services.

Access anywhere and anytime has finally motivated the leap from 'Grids' to 'Clouds'. Nowadays, the trend towards devices with limited computing and storage capacity has been at the base for many manufacturers of these kind of devices to offer "storage in the Cloud", like the Asus Web Storage Service [ASU10]. Devices like netbooks, which are an evolution of prior thin clients, have also pushed the trend towards centralising the execution of standard software in a Data Centre and providing a network based presentation (e.g. a Web browser for the Google Docs) or graphics display exporting like the RDP protocol [PH90] or the X Display Manager Control Protocol (XDMCP) [Pac].

This trend has finally brought us to the situation where everything can be provided from the 'Cloud' and 'as a Service': 'Software as a Service (SaaS), Infrastructure as a Service (IaaS), etc.' But current *x*aaS deployments, especially IaaS, count on big centralised Data Centres with a significant number of virtualized servers that are accessed from remote sites. This model is sustainable in some cases like applications with real-time constraints if the access infrastructure provides Quality of Service (QoS) guarantees and in a decentralised scenario where users might access their service through any kind of network, this might not be the case.

2.1 The virtualized 4WARD World

The 4WARD project researched new virtualization concepts for the Future Internet. This research crystallised in an architecture that provided clean interconnection points between virtual networks and three distinct and clearly defined provider profiles. These findings are documented in Deliverable D3.1 [The09]. 4WARD recognised that there might interconnections between homogeneous virtualized network environments which can be handled by Folding Lines (FLs). In case higher layer inter-working functionality is needed, 4WARD proposed the use of Folding Networks (FNs) to implement these functions.

Regarding the different provider roles foreseen by the 4WARD project in its virtual networking environment, three distinct roles were identified:

- **Infrastructure Providers**, who own physical resources and a virtualization layer that provides isolation in order to offer virtual networks to third parties through a well defined interface that allows them to negotiate and lease virtual resources.

- **Virtual Network Providers**, who provide an intermediate layer that handles (creates, destroys, modifies, etc.) virtual networks from the virtual resources they lease from one or more **Infrastructure Providers**.

- **Virtual Network Operators**, who offer virtual networks leased from **Virtual Network**

Providers to the final clients.

Although these roles can be played by different actors in the market, 4WARD also foresaw the possibility that a specific actor assumed more than one role, e.g. a Virtual Network Provider who also owns infrastructure. This model opens the possibility for this provider to temporarily lease additional virtual resources to overcome peaks in the demand or extend its footprint without the need of heavy investments in infrastructure.

3 Cloud Networking in SAIL

3.1 The Scope of virtualization in CloNe

4WARD conceived and demonstrated a concept to design and deploy networks on demand, taking advantage of the flexibility offered by virtualization. In parallel, the widespread use of virtualization in the data centre has become a relevant trend in the IT sector. Merging network and computational resources in a common virtualization framework comes as a logical next step in this process.

3.1.1 From Cloud Computing to Cloud Networking

Cloud computing (CC) relies on advances on virtualization technologies to support flexible and cost-efficient usage of computing and storage resources [AFG+10]. CC enables the rapid provisioning of new resources, scaling of resources on demand and agile self-service models. Avoiding the burden of acquiring and maintaining an expensive IT infrastructure is an appealing idea for many enterprises, especially in a harsh economic environment. This is driving a fundamental shift in how enterprise organizations use IT applications and provision computing resources.

One may wonder how, and to what extent, service provider networks will be affected by the emerging trend towards cloud services. At least two factors are likely to contribute to intensify this impact:

- Enterprises will not migrate applications to the cloud on a significant scale until a high level of reliability and performance can be fulfilled (so called *enterprise-grade* quality of service). The network infrastructure interconnecting the enterprise premises and the data centres is a crucial component of this equation. What's more, coordinated control of cloud and network resources is required to effectively offer end-to-end guarantees.

- Elasticity of the cloud, which is supposed to be one of its major selling points, will require correspondingly elastic properties of the network infrastructure. This requirement materializes not only in dynamic allocation and reconfiguration of resources but also in the capability to move those resources between different physical locations.

Several scenarios can be envisaged with regard to the connection between the Cloud service provider premises and the customer. The first scenario corresponds to the common situation today, in which cloud and network are separate service offerings, and the respective resources are oblivious of each other. This basic scenario can be enhanced by using peer-to-peer encrypted (typically IPsec-based) tunnels, transported transparently across the network that interconnects customers and computational resources, rather than relying solely on the public Internet. A well-known example of this kind of solution is Amazon's Virtual Private Cloud [Ama10]. This is a step ahead in terms of privacy and security but can do very little when it comes to guaranteeing deterministic performance and reliability. In a more ambitious scenario, computational resources and the customer infrastructure can be interconnected by a managed network service, typically a network-based VPN, which permits cloud resources and network resources to be controlled in an integrated manner. This scenario paves the way to commercial offers combining cloud and network, either by a single service provider, or by separate cloud and network providers. The ability to control cloud and network resources end-to-end in an integrated manner is a basic requirement to enable an adequate level of service for enterprises.

CloNe (Cloud Networking) addresses the challenges posed by the latter scenario and extends the scope of virtualization in 4WARD to encompass not only network resources (nodes, links) but also computational resources, such as processing and storage capacity.

3.1.2 Cloud networking with VPNs

IP/MPLS VPNs [RR06] (or simply VPNs from now on) have been a very successful technology and constitute the workhorse of managed enterprise network services, thanks to its excellent properties in terms of flexibility, scalability and cost-efficiency. VPNs can guarantee high quality and availability, measurable by end-to-end SLAs, and have proven to be a reliable and dependable network solution for small to large enterprises. To some extent, a VPN can be seen as a form of network virtualization, in the sense that it basically provides an isolated network service over a shared infrastructure. However, contrary to full-blown network virtualization, it is limited to the edge of the service provider network and consists of a simple separation of forwarding tables, rather than real virtualization of physical devices.

Unfortunately, these solutions suffer from several shortcomings when applied to very dynamic and elastic environments. Important CC requirements are fulfilled inadequately, or simply not supported by VPNs. Examples are:

- Resource Mobility: VPNs are ill suited to cope with mobility of resources. An example of such limitations is the dependence of IP addresses from physical location whenever a cloud resource is moved to a different location, the corresponding IP address must be changed accordingly, which typically has an impact in crucial network components, such as firewalls.

- Reconfigurability and elasticity: VPNs were conceived to work in a network environment which lacks the dynamism and elasticity required by CC. In fact, VPNs are supposed to be relatively static, in the sense that reconfigurations are expected to occur on a relatively large time scale.

- Integrated control of network and cloud resources: In VPNs, MP-BGP automatically handles the addition or removal of customer network resources. Cloud resources must be handled separately, which disables a common resource control framework.

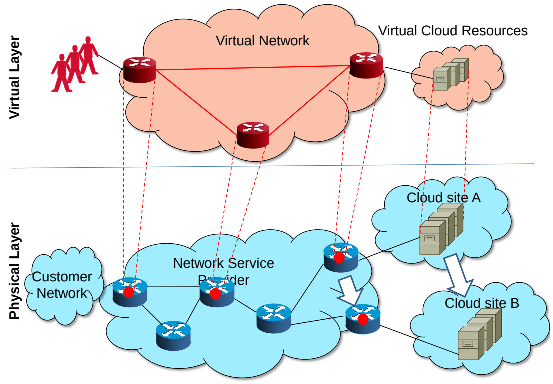

Figure 1: Mapping the virtual and physical world in the SAIL context

- Multi-domain support: VPNs are targeted primarily at single-provider environments. Although multi-domain scenarios are natively possible, there is a considerable degree of complexity involved.

In order to get around some of these limitations, an alternative solution based on Virtual Private LAN Service (VPLS) has been advocated [WGR+09]. This would fix some of the problems listed above (e.g. dependence of addressing from physical location), but unfortunately the VPLS model (or L2 VPNs in general, for that matter) has proven to be inadequate in multiple scenarios, namely because of scalability limitations.

In summary, the currently available solutions for enterprise networking by service providers lack important features that would be essential to properly accommodate the requirements posed by the integration of cloud and networking service offerings [HLMS09].

3.1.3 Long-term vision: a distributed pool of virtual resources

The advent of full-blown network virtualization, providing a real separation of virtual networks and infrastructure, will bring significant changes to this scenario: first and foremost, similarly to clouds, the ability to create, reconfigure, relocate and remove network resources on-demand and on-the-fly will become a reality. Because networks are no longer bound to the infrastructure, reconfiguration and mobility of resources is greatly simplified. In addition, virtualization offers service providers the possibility to handle processing, storage and connectivity as a common pool of virtual resources (see Figure 1), thus fully materialising the concept of Cloud networking.

Cloud networking paves the way to a redefinition of the role of operators, from mere providers of connectivity to a potentially much wider and richer service spectrum, including customized cloud services in multiple variants, e.g. Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS) and premium distribution of content. The borders between IT and networking will tend to become increasingly blurred and this is likely to have a significant impact on both fields. On the one hand, vertical integration of services by a single player may be encouraged but, on the other hand, the effective separation of networks and infrastructure offered

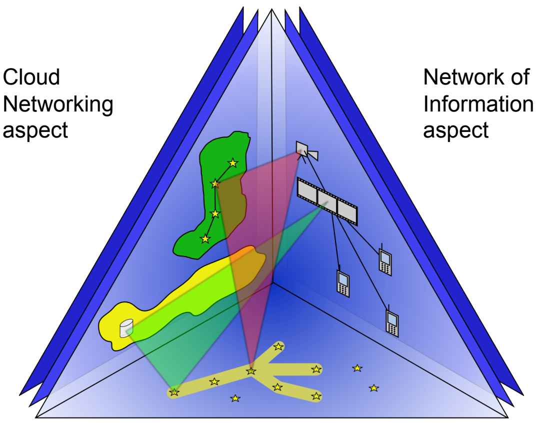

Figure 2: The SAIL Tetrahedron: relationships between the technological pillars of the project

by network virtualization is likely to foster new business models and roles. The integration of cloud services in this environment expands even further the range of possible business scenarios.

Several options are possible about the location of IT resources in the network, ranging from centralized location in few large data centres to highly scattered distribution across the network. A highly distributed approach will tend to optimize network efficiency, as the volume of traffic crossing the core will be reduced, and improve the user experience, particularly for QoS-sensitive and bandwidth intensive applications, as the network path will be shorter. On the other hand, making resources highly distributed will tend to increase operational costs, so this represents a trade-off that has to be properly evaluated.

3.1.4 Cloud networking in the scope of the SAIL project

CloNe is one of the three technological pillars of the SAIL project. It provides an infrastructure for new agile NetInf concepts and connects with the world of OConS, which wants to extend current technologies with direct application in a virtualized world, and CloNe in particular, like Generalised Multi-Protocol Label Switching (G-MPLS).

Figure 2 provides a visual representation of the relationships between the three technological pillars of SAIL, which are actually three different approaches to one and the same problem in the Future Internet: how to deliver information through a network in the most efficient way.

3.2 Providers in the new CloNe world

One of the main challenges of "Cloud Networking" in SAIL is agility. The project envisages flash network slices, i.e. collections of resources where resources are created with a high level of dynamism. In general, the provider roles envisaged by the 4WARD project, that were presented in Section 2.1, could be maintained. Models for resource sharing among domains like resource federation [COC10] will be stressed to their limits in situations where resources need to be made available at a very high rate. In the field of provider interconnection, current best practises for network interconnection [Sch08] and next generation layer-3 algorithms, MPLS and BGP-4 enhancements and Inter-AS routing as presented in [CT10] will only represent a fraction of the tools which need to be taken into account. Since network slices represent a collection of resources with specific capabilities that need to be matched in order to achieve interoperability, the new inter-provider interface will also need to extend current capability management strategies [CS02] in order to cope with new functionalities and go beyond network layer reachability information.

Despite the complexity, an inter-provider CloNe scenario presents new revenue opportunities for providers: in a globalised world, where the clients have global footprint, it might well not be economical both from a Capital Expenditure (CAPEX) and from an Operations Expenditure (OPEX) point of view for an operator to follow his clients. Operator alliances might therefore represent a win-win situation:

- for the "local providers", alliances with other providers will allow them to achieve better a utilisation of the infrastructures they deploy, as well as an additional income.
- for the "foreign operators", alliances are an instrument to keep the commercial relationship with their clients when they expand beyond their footprint. The operator follows his client without having to incur the risk of deploying infrastructure for uncertain operations of his client.

The use cases SAIL is currently developing for CloNe stress on footprint matching for virtualized services in a company with a highly mobile workforce: workers expect to have access to their service portfolio anytime and anywhere. In order to optimise their Quality of Experience while keeping network resource utilization at reasonable levels, flash network slices relocate computing and storage resources near to the workers.

4 Conclusion and next steps

The SAIL project is exploring new network technologies which provide a smooth migration path towards Future Internet technologies experimented by the 4WARD project. In the field of virtualization, CloNe promises to provide the levels of agility demanded by customers. One of the challenges for CloNe is the interconnection of providers. Current resource federation concepts, coupled with inter-AS MPLS techniques build the foundation for such an interconnection; but developments to provide the adequate responsiveness have still to come.

The benefits of inter-provider Cloud networking are cost rationalisation and risk contention, as well as, new opportunities for entrants in less developed regions, new business models for peering that better reflect the cost structure of services: in an agile environment, the resource reservation and resource activation steps gain a new significance and need to be balanced with current models based of fair and mutual resource utilisation.

The SAIL project is currently defining different use cases and scenarios which best depict the challenges it wants to tackle. Once these are defined, the definition and implementation of CloNe can begin. Inter-provider interfaces will surely have to play an important role and SAIL will profit from the fact that it is a multi-partner project, where different partners will have their local demonstration testbeds.

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